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Estimating Surface Cracking during Drying Sequence of Remolded Vertisol (Black Cotton Soil) using Fractal Approach: A Case Study of Lologo Area of Rajaf County, South Sudan

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Abstract:- The study of cracks on vertisol soils (Black Cotton Soil) has great significance for understanding the processes of soil degradation,plant nutrient uptake,and drawing strategic agricultural plans, as well as for engineering works and the development of re-vegetation techniques. An abundance of stable soil aggregates is an important indicator of good soil structure for sustainable crop production. This study aimed at a better understanding of the cracking phenomena inVertisols in order to be able to obtain a simple field technique that may reduce water losses through evaporation from cracks, yet retainstheir beneficial effects on soil profile, to estimate the development of cracks and their morphology during drying sequence, particle size distribution, its chemical and physical properties and to assess the causal relationships between the amount of soil moisture in vertisol and cracks developed and propagated.The study used a fractal approach and experiment where core-compost soil samples from a field site that has dark-clay soils mostly with very little vegetation cover were transported to the lab.The samples were left under natural conditions for four days to allow them to reach their plastic limit and the moisture content was measured using an Eijkelkamp 4-pin soil moisture sensor ML3 attached to a penetrologger display. The results indicated that moisture content reduced as the soil become drier. However, most soil samples also indicated constant moisture retention capacity (samples 1, 2, 4, 5, & 10) with a lower rate of drying hence the low development of cracks in such soil samples. Meanwhile, soil samples (3, 6, 7, 8, & 9) were found with low water holding capacity enabling cracks to develop. The results further revealedsilt soils had about 50% particle size distribution and sand soils had the lowest particle size distribution (18.35%). The pH of the vertisol soilwas found to be 8 which is extremely alkaline. Magnesium was very high in this soil compared to Calcium, Nitrate nitrogen, and phosphorus. However, humus content was found very low (2%)and considered to be of low fertility grade soils. In this case, the ability of the dark-clay vertisol to crack is attributed to the high chemical properties of the nutrient elements. Therefore, in order to assess the best type of soil that is favorable for engineering works, settlements, agriculture, and for livestock, soils must first be tested for various sustainable land uses without impacting and changing the soil structure.

Keywords:- *Particlesize distribution, soil nutrient elements, surface cracking, remolded vertisol, drying sequence, soil moisture content, black cotton soil, Rajaf Payam, South Sudan.*

I. INTRODUCTION

Worldwide, the total area covered by black cotton soil is approximately 250 million hectares with Australia, India, Sudan, Chad, and Ethiopia having 28, 24, 16, and 7% (Table 1) respectively.Soil cracking is a complex process that influences soil properties, plant growth, and the migration of water and solutes in soil [1]. Soil cracks are closely related to changes in soil structure [2], infiltration capacity, evaporative loss of soil water, and the preferential migration of soil solutes [3]. Moreover, they cause deterioration in soil water quality [4] and influence many important physical, chemical, and biochemical processes in soil [5]; [6]. The study of soil cracks has great significance for understanding the processes of soil degradation, engineering work, and underground water Pollution as well as for the development of re-vegetation techniques[1]. Black cotton soils are susceptible to a significant volume of changes with changes in moisture. In South Sudan, about 48 million hectares of land are covered by black cotton soils. During the wet season, for instance, this soil absorbsa considerable volume of water, causing it to expand or swell whereas, over the dry season, it becomes subjected to shrinkage[7]. For engineering work for instance in an experiment conducted at Skydive Pretoria, South Africa, a mixture of Fly Ash and black cotton soil can be obtained and stabilized by adding varying percentages of Fly Ash in a ratio such as 5,10,15,20,25, and 30%[8].

Soil crack morphology determines the migration routes and migration rates of water and solutes based on crack length, tortuosity, and other morphological characteristics. These in turn affect the distribution of mass on soil profiles. Hence, the study of morphological development is of

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importance to the whole study of soil cracking. However, the related studies currently focus on water infiltration and solute migration [3]; [9].The formation of cracks associated with changes in volume produced in clay soils with their variation in moisture has an important agronomic repercussion. The existence of cracks and macrospores is directly related to the transport of water and solutes in the soil [10]so any excessive increase in the area and size of the cracks in the soil can cause a rapid infiltration of water to deep layers [11], with a possible carrying with it of solutes which could pollute deep waters [12].

According to the United State Development Agency (USDA) soil classification, Vertisols are clay soils (>30% clay) that have deep, wide cracks for some time during the year and have slickensides within 100 cm of the mineral soil surface. Therefore, due to their fast water and nutrient loss, they cause deterioration in soil water quality [4] and influence many important physical, chemical, and biochemical processes in soil [5]. The study of Vertisol soils cracks has great significance for understanding the processes of soil degradation, particle size distribution, and underground water pollution as well as for the development of re-vegetation techniques with strategic plans in regard to agriculture and rural development and proper decision-making process in land use systems.

Table 1: Showing the distribution of the world's expansive black cotton soil by country

Country	The total area covered (million ha)	Percentage area covered(%)
Australia	70.5	28
India	60.0	24
Sudan	40.0	16
Chad	16.5	7
Ethiopia	10.0	4
Others	52.5	21
Total	**249.5**	**100**

II. MATERIALS AND METHODS

A. *Study Area and Sample Site*

The experiment was conducted within the University of Juba campus, Animal Farm Unit.The soil samples were collected at Lologo area,which is located south of Juba town in Rajaf Payam, west of River Nile, the world's second longest river. The sample site has soils that are mostly dark-clay soils (vertisol) with very little vegetation cover mainly grass species. The sample soilswere transported to the University of Juba Agricultural/Animal Farm Unit whichwere measured 5kgs each for control.The area is located about ½-a-mile from the river Nile in front of Central Equatoria Children Reformatory Center (Children Prison).

B. *Sampling Design, Size, and Procedures*

The study involves a layout of a field experiment with soil samples. During the sampling process, the auger was first used to remove a small portion of the soil sample to assess whether or not the soil is clay. Then a hand hoe was used to clear several spots, the forked hoe was used to dig the soil to a depth of 30 cm (root zone), and a spade was used to scoop the samples from the different spots into 10 different half-cut pieces of 50 cm×40 cm×15 cm plastic Jerricans put on a pickup and taken to the Animal Production Unit in the University of Juba where the experiment was conducted. A small sample of this soil was then scooped for analyses in the chemistry laboratory to test for nutrient elements such as Nitrogen, Nitrates, Phosphorus, Magnesium, etc.

To investigate the fractal properties of a vertisol, the soil samples in the half-cut plastic container with the size of 50 cm×40 cm×15cm were broken into soil cores and aggregates of about 5-10 cm in diameter sizes, and then water was added to dissolve the soil aggregates and expel air from the soil, then it was uniformly stirred and mixed evenly to get paste-like mixtures (liquid limit).This mixture of soils is spread on the plastic containers (Half-cut empty jerricans) and subjected tomeasurement. This was left under natural conditions for four days to allow it to reach its plastic limit and the moisture content was measured using an Eijkelkamp 4-pin soil moisture sensor ML3 attached to a penetrologger display used to read out the soil water measurements. After three days, cracks started to develop, images of the cracks in each sample were taken using a 10 GB Samsung Digital Camera, the number of cracks counted, the width and length of cracks were measured using a ruler, and the moisture content reading of each sample was also taken.

C. *Box Counting Method*

Other than the Gaussian convolution and correlation methods, the box-counting method provides one of the widely adopted algorithms for estimating the *fractal dimension* of a binary image. The box-counting principle is based on the premise that several square boxes *N* with side length *s* will be required to fully cover a binary object recorded as *N*(*s*) and the reciprocal of box size as 1/*s*. This procedure is repeated iteratively, and the *fractal dimension* is then expressed as the slope of log N(s) versus log 1/s:

$$\textit{fractal dimension}, d_f = \frac{\log N(s)}{\log \frac{1}{s}} \text{--------------------------}(1)$$

III. DATA ANALYSIS

This was repeatedly done every day as the moisture content reduces until no more secondary crack develops after ten (10) days. Crack propagation was observed; in terms of length and expressed in pixels within a defined area and the digital-colored images of the cracked vertisol that were saved in a graphic data format (jpg) were then converted into a two-dimensional black-white image by extracting other colors. Fractal dimension was estimated by either assessing the length of black lines (curves) within a defined area or expressed as a pixel. Numerical analysis of the object (cracks) was done by converting it to a binary image using numerical analysis software FRACTAL 3E where black pixels in the binary image represented the object and wereset at 0 with the background binary image set at 1.LaMotte Procedure was also used for soil nutrient elements analysis.The number of cracks, the moisture contents as the soil dries and the average depth of the cracks on the final day were then tabulated while others were represented in a graphic form.

IV. RESULTS

A. Soil nutrient elements-chemical properties in a vertisol soil sample

The results indicated that the pH of the dark clay vertisol soils is extremely alkaline with a pH of about 8. Magnesium in the dark-clay particle was depictedas very high thus, indicated by its test result as very high. This is followed by calcium properties in the dark- clay indicated by 350 kg/hectare. However, humus content (2%)is very low in the vertisol soils (Table 2).

Table 2: Analysis of soil nutrient elements using LaMotte Procedure

	SOIL NUTRIENT ELEMENTS (Kg/ha)							
Nutrient	PH	Nitrate Nitrogen	Phosphorus	Magnesium	Calcium	Sulphate	Ferric iron	Humus
Vertisol	8.0	45.36	68.03	Very high	350	100	4.45	2% Low

B. Soil physical properties and determining particle size distribution in a vertisol soil sample

Sandy soils exhibited the lowest particle size distribution (18.35%). This is followed by clay particles with 28.2%. However, the sieve analysis found silt soils possess a higher proportion of the total particle size distribution of over 45%. This trend poses vertisol soils to easily crack and had significant variations in the soil particle distribution(Table 3).

Table 3: Analysis of soil physical properties using LaMotte Procedure

Soil type	% particle size distribution
Sand	18.35 %
Silt	49.09 %
Clay	28.20 %

C. Particle size distributions in a selected sample of 63.6 grams of a vertisol soil

The results revealed soil of particle size 0.25mm and 0.125 mm possesses higher cumulative weight compared to all other particle sizes (Figure 1). The analysis further indicated that the weight of soil particles sampled alone is smallest when passed through sieve size 2, also with higher void sparsely distributed (0.94gm). This is followed by soils sieved at 0.063mm, <0.063mm, 1mm, and 0.5mm reported by 1.23 gm, 2.14 gm, 10.73 gm, and 12.48 gm, respectively. However, particles sieved at 0.25mm had large soil particles (Table 4).

Table 4: Particle size distributions in a selected sample of 63.6 grams of a vertisol soil

Sieve size (mm)	Wt. of the container alone (gm)	Wt. of soil + Wt. of container	Wt. of soil alone (gm)	Distribution (gm)	Cumulative %
2	52.17	53.11	0.94	1.48	1.48
1	42.41	53.14	10.73	16.87	16.87
0.5	35.69	48.17	12.48	19.62	36.49
0.25	30.95	49.69	18.74	29.47	65.96
0.125	33.82	51.16	17.34	27.26	93.22
0.063	30.27	31.50	1.23	2.94	96.16
<0.063	-	-	2.14	3.84	100.00

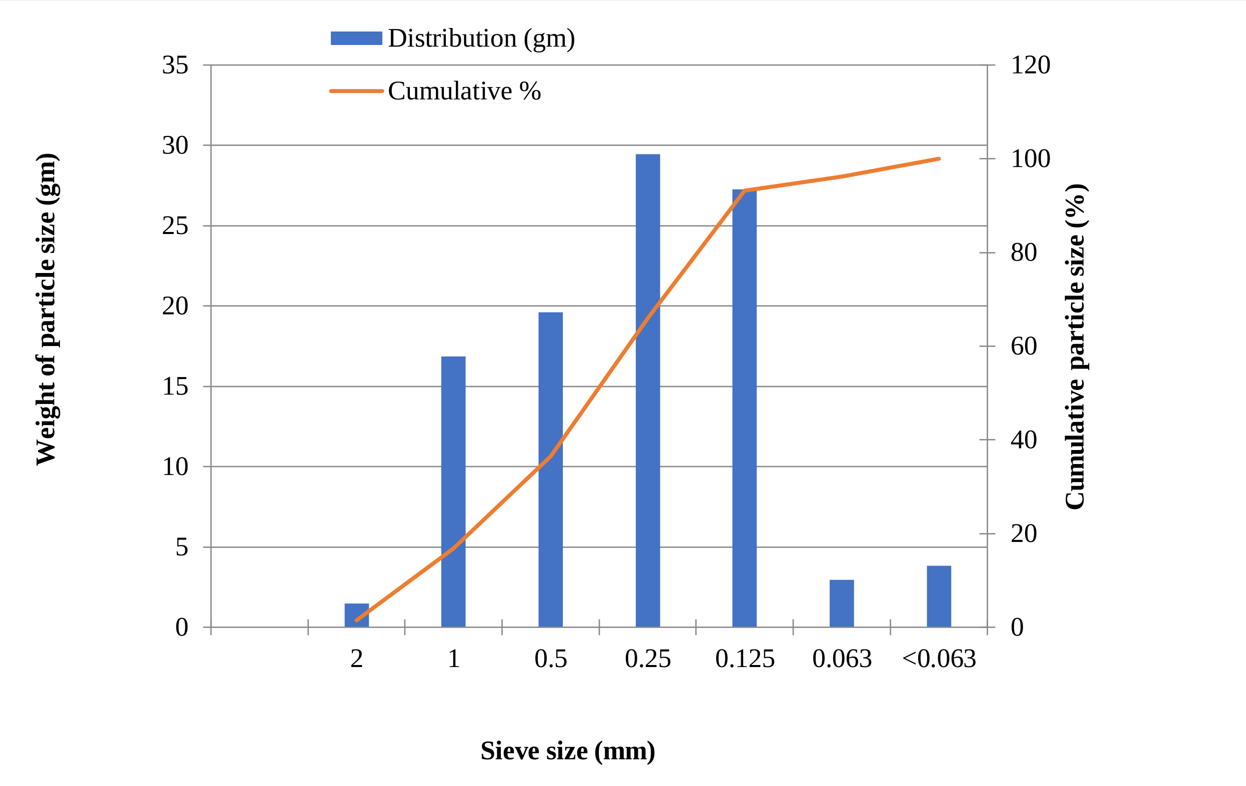

Fig. 1: Particle size distribution of a selected vertisol soil sample

D. Measurement of Soil Moisture Contents (SMC) in ten (10) different soil samples within ten consecutive days

The experiment results indicated that moisture content reduces as the soil become dry. However, most soil samples also indicated constant moisture retention capacity (sample1, 2, 4, 5 & 10) with a lower rate of drying hence the slow development of cracks in such soil samples (Table 5). Meanwhile, soil samples (3, 6, 7, 8, & 9) with low water holding capacity release water faster to other mediums exposing it to evaporate, therefore, reducing its moisture content and enabling cracks to develop faster. It was also observed that soil samples (2, 3, 5, 6, 7, 8 & 9) regained higher moisture contents as repeatedly measured on adaily basis(Table 5).The correlation of $r^2 = 0.833$ shows there is a strong positive correlation i.e.,the independent variables or the model explained over 80% of the variations in the target variables(Figure 2).

Table 5: The Soil Moisture Contents (SMC %) measurement in ten consecutive days

Day /Sample	Soil Moisture Content (SMC %)									
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sample 6**	**Sample 7**	**Sample 8**	**Sample 9**	**Sample 10**
1	45	48	47	46	44	45	48	46	46	45
2	40	45	45	43	43	0	0	45	45	0
3	35	42	40	37	40	42	43	42	44	43
4	34	40	36	37	38	41	40	40	39	41
5	31	40	40	33	37	38	39	41	32	40
6	31	37	37	33	37	39	38	38	31	38
7	30	38	39	33	38	37	40	37	34	38
8	26	35	32	31	35	36	36	36	33	35
9	23	27	24	20	16	21	28	24	23	4
10	0	16	23	16	14	7	20	10	20	2

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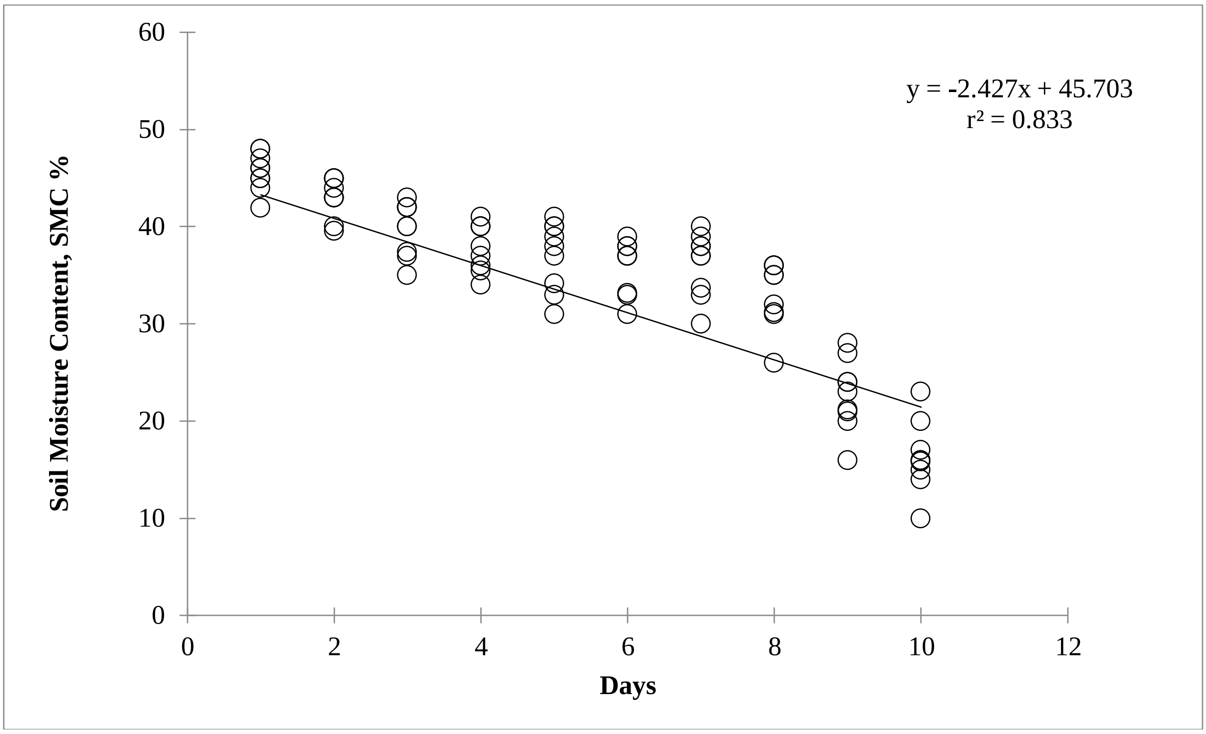

Fig. 2: Relationship in Soil Moisture Contents ofdifferent vertisol soil samples in ten days

E. A sequence of crack development and propagation behaviorin soil sample 2 of a remolded vertisol

The results indicated that moisture content initially for date zero (0)was found to be 48%, cracks started to develop from day 1 to day 2, and after this point in time, no more cracks developed from day 3, day 5through day 29. Cracks continue to increase on day 30 and on the last day 32. However, the already-developed cracks onday 1 and day 2 (SMC=45% and SMC=42% respectively) only continue to increase in size, length, and width(Figure 3).

Day 0; SMC 48% Day 1; SMC 45% Day 2; SMC 42%

Day 4; SMC 40% Day 6; SMC 37% Day 7; SMC 38%

Day 8; SMC 35% Days 9 and 10; SMC 27% Day 30; SMC 22%

Day 32; SMC 16%

Fig. 3: Sequences of crack development and propagation behaviorin soil sample2 of a remolded vertisol

F. Relationship between log (1/s) and log N(s) of sample 2 of a Black Cotton soil (Vertisol)

In this research, the analysis of the cracking phenomenon was performed with the software FRACTAL3. As in Fig. 4, the logarithm of 1/s was plotted against the logarithm of N(s) of the cracks of sample 2 in 9 consecutive days. A linear relationship between the logarithms of Log (1/s) and Log N(s) could be observed (Figure 4). Based on Eq. (1), the fractal dimension of the cracks was on average 1.550 indicating that, the cracks in the case of sample 2 had fractal properties. The fractal dimension of cracks in soil sample 2 was slightly higher than after filtering and skeletonization of the digital images. Furthermore, the correlation of $r^2 = 0.97$ shows there is a strong positive correlation with the model that explained over 95% of the variations in the target variables (Figure 4).This phenomenon suggests that cracking may influence the complexity of the microstructure of soil samples.

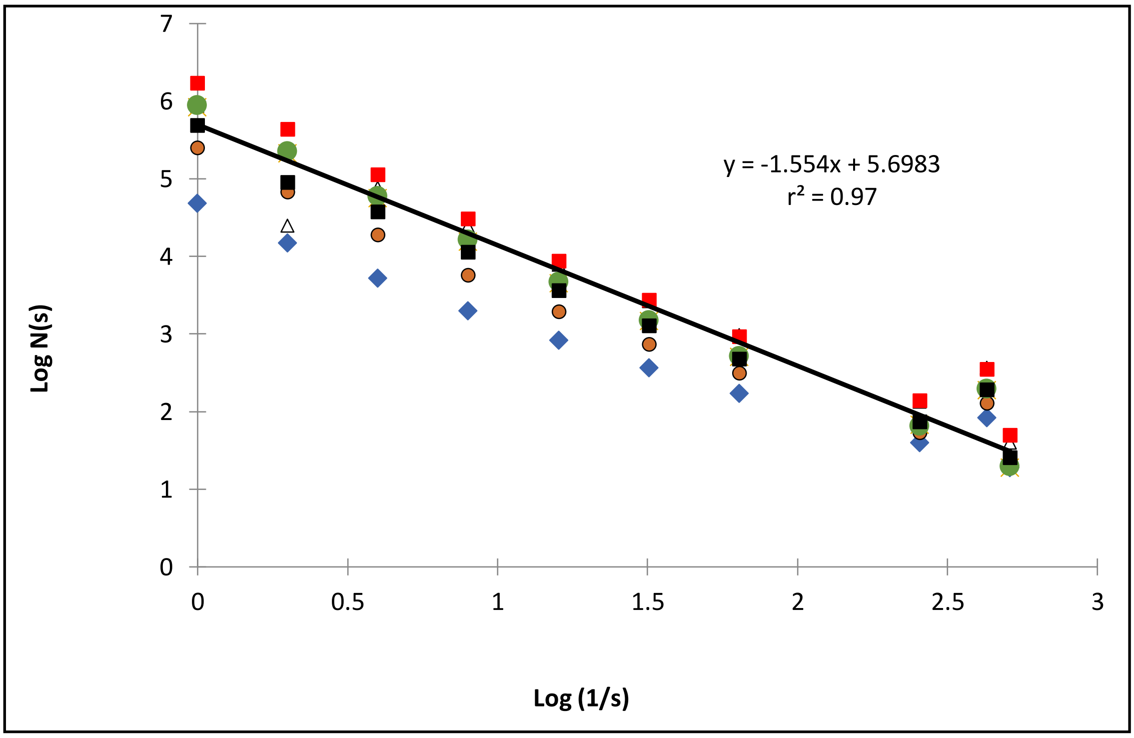

Fig. 4: Relationship between log (1/s) and log N(s) of sample 2 of a Black Cotton soil (Vertisol)

G. The number of cracks developed and propagated in(0-10) mm width sample soils

The results indicated that soil samples (1, 9, 8, 2 & 6) in this dimension of (0-10)mm possess a larger number of cracks in that order respectively(Figure 5). However, samples 3, 4, 5, 7 &10 increased in size or dimensions to (10-20) mm (Figure 5) as they possess a smaller number of cracks.

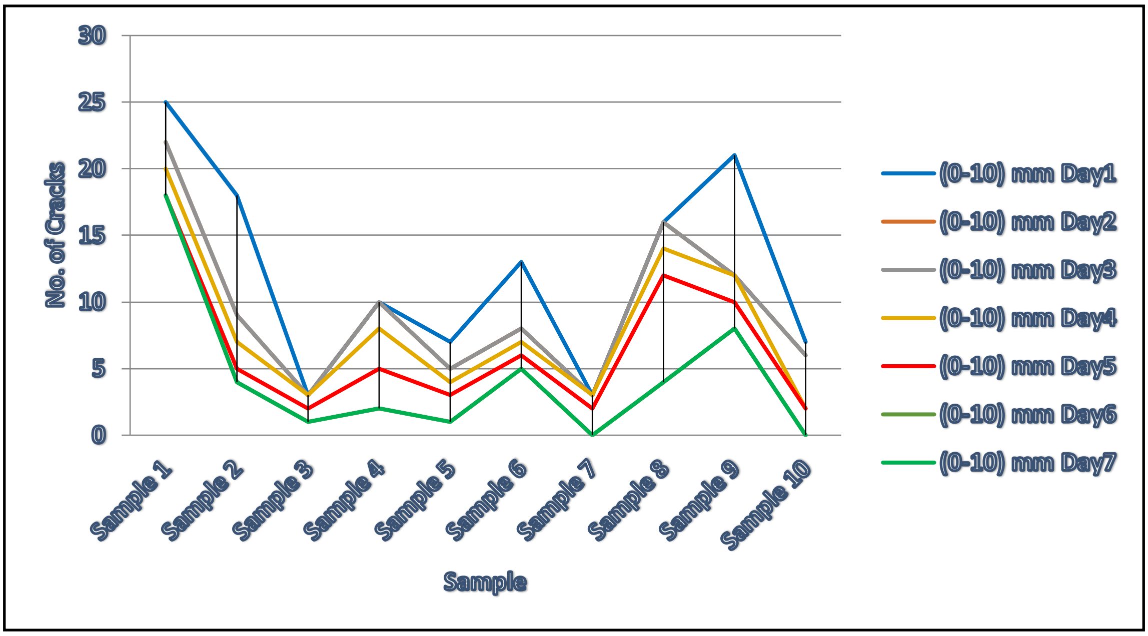

Fig. 5: Showing the number of cracks propagated in (0-10)) mm soil samples per week

H. The number of cracks developed and propagated in(10-20) mm width sample soils

The results in Table6 indicated, onday 1, all the soil samples revealed no cracks. However, onday 7, samples (1, 2, 4, 6, 8, & 9) showed a significant number of cracks in this dimension. Meanwhile, samples 5 & 10 are relatively expansible into a dimension of 20-30 mm. Samples 3 & 7 are highly expansible into higher widths (Figure 6).

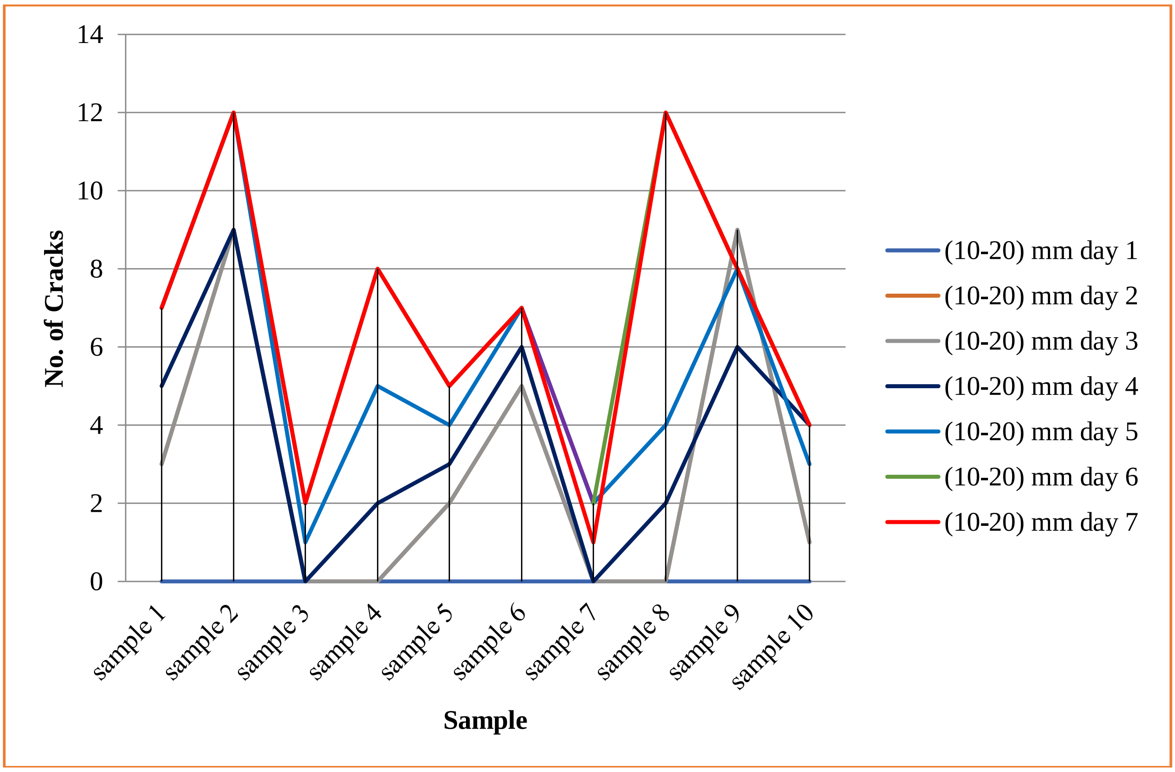

Fig. 6: Showing the number of cracks propagated in (10-20)) mm soil samples per week

I. The number of cracks developed and propagated in(20-30) mm width sample soils

The results showed no cracks from day 1, day 2, and day 3for all the soil samples with samples 1, 3, 4, 7 & 8 having no cracks at all for the whole of the week. This is due to the cracks in the previous dimension i.e. (10-20) mm not being expansible. The measurement also revealed that samples2,5, 6, 9&10sustained a higher and increased number of cracks with sample 9 leading compared to other samples (Figure 7). This might be attributed to the porous soil with large particles that dries into extreme depths.

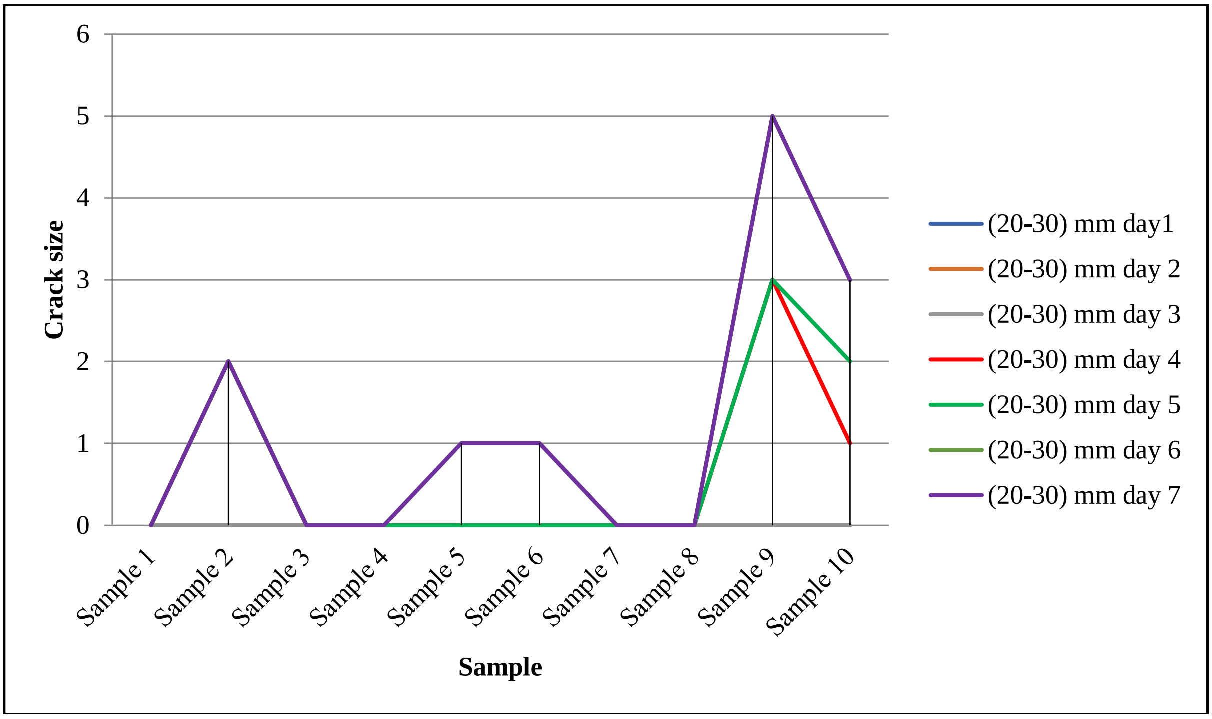

Fig. 7: Showing the number of cracks propagated in (20-30)) mm soil samples per week

J. Relationship between moisture content and number of cracks in one Vertisols sample

The moisture content remains high onday 1, day 2,day 3, and day 4 with a higher number of cracks inthe(0-10) mm width in a decreasing dimension (Table 6). As the moisture content reduces, the pattern of distribution in cracks increases with a considerate distribution of the initial number of cracks in a reduced manner.When water content tends to zero with dry soils from day 8-day 12, the initial crack number inthe dimension of (0-10) mm takes the same trend with areducing number of cracks in the dimension of (10-20) mm.Overall, as the moisture content in the soil samples decreases, the number of cracks increases especially in the dimension (20-30) mm (Table 6).

Table 6: Relationship between moisture content and the number of cracks in one vertisol sample

Days	Moisture content	Number of cracks in various measured widths		
	%	(0-10) mm	(10-20) mm	(20-30) mm
day 1	41	7	0	0
day2	40	6	1	0
day 3	38	6	1	0
day 4	38	2	4	1
day 5	35	2	3	2
day 6	4	1	3	3
day 7	2	0	4	3
day 8	0	0	3	4
day 9	0	0	2	5
day 10	0	0	2	5
day 11	0	0	1	6
day 12	0	0	0	7

K. The measurement of soil depths of different vertisol samples during the drying sequence

The results of the experiment indicated thatduring the initial day1 when the soil samples were wetted, sample 9 took the highest depth when measured. Soil samples 8, 6, 7, & 2 also showed significantly higher depths compared to samples 1, 5 & 10. This could be due to the soil being soft and moistened. However, samples 4 & 3 have low depths due to shrinkages when drying with bulk soil particles.During the last day of measurement, all the soil samples have shown a significant drop in heights (depths) ranging from 3.3-4.7 cm (Figure 8).

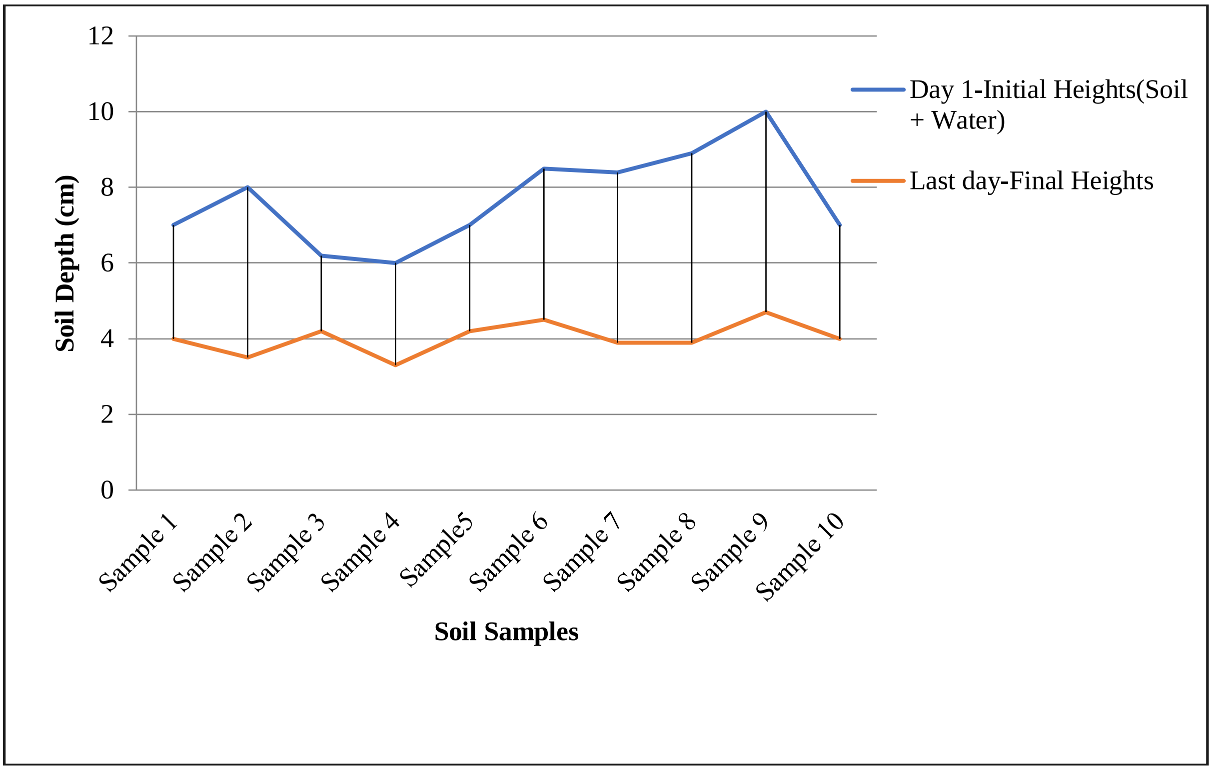

Fig. 8: Showing the measurement of soil depths (cm) of different soil samples

V. DISCUSSION

From Table2 above, the result depictedextreme alkaline pH of the dark-clay Vertisol soils with a pH of 8.This conforms to the results generated by [13] and [14]. The dark-clay particle contained very high levels of Magnesium compared to the nitrate nitrogen, with very low levels of humus content in the Vertisol soils. This does not support agriculture as compared to loamy soils. Therefore, the ability of the dark-clay Vertisol to crack could be due to the high Vertisol chemical properties of the nutrient elementsas reiterated bythe findings of[13] and [15].

According to its particle size distribution,vertisols results revealed sand soils having the lowest particle size distribution (18.35%), the trend is followed by clay particles with 28.2%. However, silt soils possess a higher proportion of the total particle size distribution forming about 50%due to variation in the patterns of soil distribution, making the vertisols viable to cracking especially when subjected to normal conditionsas in the findings of [16].

The findings showed that moisture content in vertisol soils reduces as the soil become dry. Soil samples (3, 6, 7, 8, & 9) (Table 5) had low water holding capacity andrelease water faster to other mediums exposing it to evaporate, therefore, reducing its moisture content and enabling cracks to develop that do not support agricultural production. It was also observed that other soil samples also retainedand sustained higher contents of moisture after being measured daily especially when the measuring instrument is immersedin the region of moisture concentration in the soil samples, especially in samples 1, 2, 4, 5 & 10 (Table 5). Therefore, we assessed the drying-wetting conditions of the soils based on the measured values whichconfirm with findings of [17]. This could be due to variables in Hydraulic gradients. A similar trend was also presented by [18]that Hydraulic conductivities measured at the same soil water contents increased eightfold after an extremely wet fall and winter followed by a period of drying.This is also coupledwith the principles of water potentials that water moves from the region of higher concentration to the region of lower concentration.

The analysis in Figure 5, indicated an equal number of soil samples that possessboth very tiny sizes of cracks but, have a larger number of cracks. However, samples 2 & 8 also show a significant reduction in their crack sizes and numbers which develop into the dimension of 10-20 mm. The increase in sizes or dimensions with samples 4 & 10 completely immersed into it is attributed to its particle sizes being large compared to that of the other samples. According to [19]finding, the effect of wetting-drying cycles on the soil-water retention curve was not significant. The moisture content decreased as induced by drying, and was strongly affected by the intensity of cracks on the molds of soil samples. This seemed to contradict the finding of this study.

The experimental measurement of cracks on soils with 10-20mm widthson day1, indicated that all the soil samples had no cracks. However, onday 7, most samples (1, 2, 4, 6, 8, & 9) showed a significant number of cracks,although tiny in size. This might be due to a homogeneous mixture of the soil and poor cracking conditions. Samples 5 & 10 are found relatively expansible into a dimension of 20-30 mm with samples 3 & 7, highly expansible into higher widths. This is in line with the findings of [20]. The measurement results also revealed that samples 2, 5,6, 9 & 10 sustained higher numbersand increased sizes of cracks compared to other samples. This might be attributed to the porous soil with large particles that dries into extreme depths.This is true with the observation in studies conducted by [21] and [22], who reiterated that the magnitude of cracking was alsoobserved to increase following the intensity of wetting-dryingcycles. The finding of the study is also in support of results found by[9] and [23].

As the moisture content remains high for instance, as revealed onday 1, day 2, and day 3, the higher the number of cracks with their sizes in a decreasing dimension. As the moisture content reduces, the pattern of distribution in cracks increases with a considerate distribution of the initial number of cracks in a reduced manner.When soil moisture content tends to zero with soil drying, the initial crack sizes and number from(0-10) mm take the same trend with only an increasing number of cracks in the dimension of (10-20) mm and (20-30) mmrespectively. The finding is in conformitywith that of [20] and [24].

In general, for such vertisol soils, as the moisture content in the soil samples decreases, the sizes of cracks initially increase gradually,especially for (0-10) mm width, and drastically increase in the dimension of (20-30) mm.During the initial day 1, it is noted that when these soil samples are wetted, sample 9 took the highest depth when measured. While samples2, 6, 7, &8 also showed significantly higher depths compared to samples 1, 5 & 10. This could be due to the soil‘s soft and moiststate, a study reiterated by [25]. However, samples 3&4have low depths due to shrinkages when drying having bulk soil particlesas in [19]findings.The measurement conducted on the last experiment day showed that all the soil samples have a relative drop in heights (depths) ranging from 3.3-4.7 cm(Figure 8). This drop is attributed to water being leached out during drying. This compared soil samples favorably in their capacity for water retention and crack intensity with sample9 owing the fastest to cracks while sample4 doesnot crack easily.

VI. CONCLUSION

The results obtained in thisfield experiment showed that the cracks' number and size at the end of the experiment increased as the soil dries up. Cracks observed in the studied potted soil samples were far deeper. An increase in the cracking intensity seemed to be related to the soil clay content and water regimes. The cracks at the end of heavily dried Vertisols are of major importance in facilitating water movement down the soil samples and could be a source of huge extra water losses through evaporation from the cracks' soil surfaces [26].The fractal dimension of cracks in soil sample 2 was slightly higher than after filtering and skeletonization of the digital images.This phenomenon suggests that cracking may influence the complexity of the microstructure of soil samples.

Cracks can cause an increased loss of soil moisture with depth, through evaporation from the crack surface, even though this loss may be significantly reduced under a fully established experiment. These cracks could also be the reason for a considerable increase in the irrigation water requirements at the time of the first irrigation after the dry season by many agricultural bodies. Yet, soils in semi-arid regions are easily eroded due to large cracks causing heavy leaching of moisture contents to the deeper soil layers,especially with events of heavy irrigation or high rainfalls. Thesecracks may also cause serious soil physical damage to crop roots that may lack nutrients and water due to the leaching.

VII. POLICY IMPLICATIONS AND RECOMMENDATIONS

From the research findings above, it can be recommended to the government, soil users,engineers, and other land use stakeholders that,

The government should carry out a comparative baseline survey on the soil properties in other parts of South Sudan to assess the best type of soil that is indistinguishably favorable for infrastructure development, roads, bridges, settlements, agriculture, and for livestock, and/or other land uses. 2) The government should encourage capacity building and training of soil scientists who could help analyze soil chemical and physical properties into usable scales of water movement, flood gradients, cracking patterns, and particle distribution to sustain natural resources base. 3) To overcome the limitations of our study, which were the estimation of antecedent and current soil water content, at only one measurement site, further field studies for monitoring long-term vertical and horizontal shrink–swell processes are needed. 4) This research results showed that the tested soils are suitable for agriculture (crops and animals) production but not for settlements and therefore, the government and other land use stakeholders should encourage the local community to participate in agriculture and supportthem through extension services by providing agriculture inputsand extension services to tackle food security and livelihoods constraints. 5) Bick layers and builders and other soil molding activities (pottery) are not suitable in this soil and therefore, for successful engineering work/use, a proportionate ratio of soilmixture to mold is necessaryto build strong and firm structures that are durable in nature and, 6) Soil testing should be a priority to ascertain the right soil grades for different land uses including agricultural and other activities which need to be integrated into policy frameworks of relevant government and public institutions countrywide.

CONFLICT OF INTERESTS

There are no conflicts of interest declared by the authors of this article from their study.

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ANNEXES

Plate 1: Preparation of vertisol soils for an Experiment to determine cracks properties

Plate 2: Testing for vertisol soil nutrients elements in Juba University Bio Laboratory/2018